METHODS

ACCUMULATION OF PHOSPHORUS AND POTASSIUM WITHIN LEAVES OF TREES AND SHRUBS AND THEIR LEACHING FROM LITTER DURING THE AUTUMN-WINTER PERIOD

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The problem of increasing the productivity of forest plantations is hampered considerably by an insufficient knowledge of the small biological turnover of plant mineral nutrients. This problem is important chiefly because forest plantations grow for a long time at the same place, and also because every year they return to the soil surface a considerable portion of elements obtained from the soil. The rapidity of the liberation of these elements from the litter and their repeated utilization by plants determine to a considerable degree the possibility of their systematic replenishment within the soil; because of this, the productivity increases in plantations.

Among these elements potassium and phosphorus play an important part in plantation growth. The content in these elements is limited within most soils, and they are replenished very little through the weathering of parent material. According to Rode (6) the upper layers of forest soils, podzolized to various degrees, contain 0.81%-2.24% of K_2O and 0.05%-0.38% of P_2O_5. These amounts, even as total amounts, cannot be considered high, but they are further reduced when considered in available quantities that are much smaller.

The importance of potassium and phosphorus in plant physiology is well known. Thus, according to Ratner (5) potassium influences the photosynthetic process greatly, although it does not form part of the photosynthetic products itself. Physiological research has further established that potassium affects the dispersion of protoplasmic colloids, their water content, viscosity, elasticity, etc., which in turn determine the degree of plant resistance to low or high temperature (winter hardiness) and to water regime (drought resistance).

Even more varied and important to plants is the part played by phosphorus. It shares in the composition of protoplasm, cell nucleus and many ferments that regulate biological processes within plants. Phosphorus, under the form of phosphoric acid, participates directly in the processes of respiration and fermentation (2) and also in the process of photosynthesis. According to Kursanov et al (3), the movement of carbohydrates in plants and, in part, their transport from leaves to storage organs, is influenced by phosphoric acid.

The importance of potassium and phosphorus in the vital processes of the trees and shrubs in forest plantations requires the investigation of both the seasonal plant requirements in these elements and of the amounts and the rate at which they are liberated from litter leaves and needles. Unfortunately, these problems have been investigated little.

During the years 1955-1957, research was conducted on the dynamics of accumulation of ash elements in growing leaves and needles of a number of trees and shrubs and their liberation from forest litter during the winter period (from the time of defoliation to the beginning of new growth). The method of research was relatively simple. Every month immediately from the beginning of full opening of leaves, in specially selected experimental areas, tree leaves (needles) were picked from almost all trees in various parts of the crown (to achieve objective data). The collected leaves were dried the same day and after having been ground were stored in a dry place until the time of analysis. In order to avoid dust contamination, the leaves were thoroughly wiped before drying.

In order to ascertain the rate at which potassium and phosphorus are leached out of the litter, it was collected at the time of mass defoliation and again in spring of the following year, when trees and shrubs began their vegetative activity. The preparation of the litter for analysis was the same as that of green leaves.

The analysis of leaves for potassium and phosphorous content was carried out by the department of forest crops of the Bryansk Forest Institute. Potassium was extracted by 1 N solution of sodium chloride after 24 hours of treatment. This extracted both the soluble and

exchangeable potassium. Its quantitative determination was done by means of the Pieve procedure using the cobalt-nitrite sodium method of the smallest concentration of precipitate. Phosphorus was extracted from the ground litter or leaves by a 0.2 N solution of hydrochloric acid, its content determined by colorimetric method. Analysis and calculation refer to air-dry material. In order to determine the amounts of phosphorus and potassium in litter or leaf substance, their content in ash was determined by means of ignition in the oven at red incandescence.

The accumulation of ash elements within the leaves is strictly correlated with local conditions. Research took place in the nursery of Beloberezh in the forestry department of the Bryansk Research Forest, where in 1948-1949 shrub seed plots were started. The nursery soil is poor, medium-podzolized, sandy, overlying fluvio-glacial sands, fresh. Because of depletion through plowing, the humus content in the A Horizon is low - 2.1%. Research also included three permanent experimental plots planted with pine, 36-40 years old, of the Karachinsko-Krylov forest of the same farm.

Experimental Plot No. 4 was in a pine-euonymus forest in relatively dry, shallow, sod-calcareous, clay loam soil underlain at a depth of 0.3 m by a chalky marl. Experimental Plot No. 5 was located in a pine-basswood forest with fresh, weakly-podzolized, sandy soil, underlain at a depth of 1.1 m by glauconite sands with phosphorites. Experimental Plot No. 7 was located in a forest of pine-Vaccinium; here the soil was peaty-medium-podzolized, sandy, with indications of gleying and with the presence, at a depth of 0.8 m, of phosphorites. The ground waters reach to the surface in autumn and in spring, and in summer descend to 0.5 m.

A short description of trees of the pine plantations, in which the experimental plots were located, is given in Table 1.

The results of the investigation of the total content in ash within the leaves of trees and shrubs that grew in the nursery are given in Table 2. As can be seen in this table, the ash content within the leaves of all species increases gradually from the opening of the leaves to the end of the growing season and defoliation. Except in two cases (pine and Amorpha) the increase amounts to 4%-87%, on the average 33%, of the initial ash content. It can also be observed that at the beginning of the growing season, the ash content within the leaves attains a considerable amount, 3%-11%, but in the majority of species it is 4%-7%. At the beginning of the growing season, together with leaf growth, there is a sharp increase in their ash content, which amounted to 0.25%-0.7% daily between April 27 and June 10, 1956. Considering the great number of leaves, such an intensive increase indicates that the period of leaf development is a time of great stress in relation to the plant requirements as regards the ash elements.

The accumulation of ash within the leaves continues throughout the following growing season, but the rate of increase is smaller. The increase in ash content during this time amounts to 0.01%-0.02% on the average; the maximum is 0.06%. But, because of the long growing season, this ash content increases in fall considerably. The ash content of leaves of shrubs (understory canopy) is somewhat higher (6%-7%) than in tree species (3%-6%).

Table 2 shows that the decomposition and leaching of the organic substance from the overwintering litter is somewhat more rapid than the leaching of the ash elements, which brings about an accumulation and increase in ash elements. In the majority of species the ash content increased 2-3 times, although in individual cases this increase was small (hazelnut, oak, etc.).

Habitat has a great influence on ash accumulation within leaves. Table 3 shows that the ash

Table 1

Characteristics of forest stands of the experimental plots in pine plantations (Karachizhsko-Krylovskoye forest of the Bryansk Forest Research Station)

Characteristics of stands	Experimental plots		
	No. 4	No. 5	No. 6
Designation of plots	54-b	58-b	80-k
Age of a plantation (years)	36	44	32
Average diameter, cm	15.8	26.3	14.2
Average height, m	15.8	23.4	13.2
Crown cover	0.94	0.81	0.97
Number of stems per ha	1850	700	1700
Site quality index (according to Tyurin)	I	I-a	III

Table 2

Ash content in leaves of trees and shrubs growing in the nursery of Bryansk Forest Research Station (collection 1956)

Species	Ash content in % of air-dry weight and collection dates					
	June 10	July 12	Aug. 4	Sept. 1	Oct. 1	Litter for 1955
Mountain ash	4.53	4.92	5.86	5.74	6.89	12.40
Alder buckthorn	5.53	4.74	4.99	5.26	6.51	21.98
Small-leaf basswood	7.93	8.46	9.74	8.61	8.74	—
Hazelnut	7.53	6.83	8.09	7.59	9.25	10.38
Honeysuckle	5.44	4.95	6.83	7.69	—	—
European euonymus	11.01	9.94	8.90	11.30	12.68	—
Barberry	4.34	4.36	5.50	4.47	7.47	—
Tatar maple	4.01	3.99	5.00	4.92	6.04	11.71
Service berry	—	5.49	5.37	5.82	5.95	10.71
Privet	3.16	2.76	2.43	4.30	4.46	12.82
White dogwood	10—26	8.69	8.02	9.33	10.66	—
Red elder	9.78	10.85	11.91	12.14	15.28	30.78
Yellow acacia	7.37	7.75	9.52	10.71	10.12	12.48
Virginian cherry	4.60	5.00	4.71	5.62	6.57	11.88
Sylvestris pine (needles—one year)	3.02	2.42	2.15	2.38	2.72	—
Amorpha	4.79	3.58	4.36	4.31	4.27	10.34
Warty birch	4.40	4.99	3.93	4.72	4.67	—
Aspen	6.95	6.20	7.85	8.78	8.86	—
Siberian larch	3.45	3.26	3.43	5.03	6.44	—
Cherry oak	3.83	—	3.51	6.30	6.92	7.04
Hawthorne	6.61	—	7.23	7.24	7.94	12.64

Table 3

Ash content in leaves of shrubs and trees growing in pine plantations (collection 1956)

Species	Type of pine forest	Ash content in leaves in % of air-dry weight and collection dates				
		May 27	July 1	August 5	Sept. 5	Oct. 7
Mountain-ash	Vaccinium	8.61	8.88	8.47	8.45	7.86
	Euonymus	8.26	9.24	10.89	9.56	10.13
	Basswood	8.45	9.42	10.50	9.76	11.38
Alder buckthorne	Vaccinium	6.40	7.68	7.79	8.07	9.13
	Euonymus	—	7.52	9.66	9.35	10.86
Hazelnut	Euonymus	8.75	8.80	9.88	10.06	11.29
	Basswood	7.97	8.67	10.46	9.32	11.45
Euonymus	Euonymus	7.48	7.76	10.10	10.43	9.50
	Basswood	7.26	8.87	10.23	9.69	12.46
Small-leaf basswood	Basswood	9.00	7.88	8.81	8.50	10.32
Norway maple	Basswood	8.76	6.71	7.83	8.11	10.24
	Euonymus	—	7.51	8.84	10.78	12.37
Honeysuckle	Euonymus	10.54	10.04	16.46	15.78	15.08
White dogwood	Euonymus	9.75	12.17	15.24	15.57	15.31
Warty birch	Vaccinium	7.45	6.28	6.28	7.05	5.38
Aspen	Vaccinium	9.69	9.37	8.33	9.76	9.35
Gray willow	Vaccinium	9.21	7.41	9.27	10.75	10.31
Cherry oak	Vaccinium	—	4.86	5.45	6.21	6.48
Yellow acacia	Arboretum	7.54	8.05	12.20	12.43	12.87

content of the majority of species in pine plantations is considerably higher than in those growing within the nursery. Thus, for example, the ash content in the leaves of mountain ash is almost twice as high, and in other species 20%-40% higher. Also interesting is the difference in ash content according to the type of forest. The highest ash content was found in the species growing in the pine-basswood forest; it is somewhat lower in the pine-euonymus forest and lowest in the pine-Vaccinium forest. However, these differences are not too great and they appear only at the end of the growing season, when the ash content of some species attains 12%-15%. In spring the rate of increase is higher in pine plantations than in the nursery. The following summer-autumn period the increment rates are relatively uniform.

Potassium content in leaves of trees and shrubs, as can be seen in Table 4, varies within wide limits: 1.37%-0.31%; on the average, it is 0.5%-0.8%. It can be observed that species with higher ash content contain more potassium, although there are exceptions. Potassium content within leaf ashes varies from 3%-18.5%; on the average it is 10%-12%. The change in potassium content indicates that plants require, from the very first period of life, large quantities of potassium which amount to 14 kg for each metric ton of air-dry leaves, even in the poor nursery soil. Keeping in mind the short period of leaf development (about 2 weeks), it follows that the increase in potassium content is rapid and that it attains 0.03%, or about 0.3 kg per day for a metric ton of air-dry leaves. In species with a low potassium content, these amounts are naturally lower and attain 0.1 kg per day.

During the growing season, the potassium content of leaves of trees and shrubs decreases gradually and noticeably in proportion to their age. Toward the end of the growing season this decrease reaches 0.2%-0.8% of air-dry leaves, or 19%-20% of the initial content. We may assume that during this period the transfer of potassium from the soil into the plant continues, but it is carried to other parts of the plant which grow at a greater rate (bark, wood) at this time. Potassium migrates there from the leaves, together with the products of assimilation. In this way the plant can accumulate in its non-deciduous parts a considerable amount of potassium, which is necessary to mobilize it rapidly and transfer it into growing leaves during the spring. With the falling of leaves only 60%-15% of the initial amount of potassium is lost to internal circulation; the remaining amount (40%-85%) is kept within the wood for re-use (re-utilization).

Potassium content within leaf ash also decreases accordingly; at the beginning of the growing season it attains 10%-12%, but as leaves grow (age) it gradually decreases to 2.5%-10%

Table 4

Potassium content in leaves of trees and shrubs growing in the nursery of the Bryansk Experimental Forest Station (collection 1956)

Species	Potassium in % air-dry leaf material					Potassium in % of ash content				
	June 10	July 12	Aug. 4	Sept. 1	Oct. 1	June 10	July 12	Aug. 4	Sept. 1	Oct. 1
Mountain ash	0.443	0.438	0.426	0.428	0.239	9.78	8.92	7.28	7.48	3.45
Alder buckthorn	0.860	0.465	0.460	0.453	0.164	15.55	9.83	9.23	8.61	2.52
Basswood	1.371	1.188	1.461	1.145	0.558	17.25	14.05	15.01	13.30	6.39
Hazelnut	0.952	0.746	0.724	0.727	0.444	12.64	10.92	8.95	9.58	4.30
Honeysuckle	0.307	0.231	0.146	0.202	—	5.65	4.67	2.14	2.62	—
Euonymus	1.371	1.200	1.132	1.221	0.727	12.43	12.07	12.72	10.80	5.74
Barberry	0.583	0.417	0.568	0.411	0.440	13.44	9.57	10.32	9.18	5.89
Service berry	—	0.690	0.658	0.658	0.440	—	12.56	12.26	11.30	7.40
Tatar maple	0.542	0.308	0.305	0.347	0.364	13.51	7.72	6.11	5.72	6.03
Privet	0.451	0.272	0.188	0.196	0.096	14.28	9.84	7.74	4.60	2.16
Dogwood	0.940	0.723	0.430	0.488	0.244	9.17	8.33	5.36	5.23	2.27
Elder	1.424	1.215	1.232	1.169	0.876	14.57	11.17	10.32	9.62	5.73
Acacia	1.178	0.972	0.805	0.810	0.732	15.99	12.53	8.45	7.56	7.23
Cherry	0.678	0.447	0.445	0.595	0.364	14.93	8.94	9.55	10.62	5.54
Pine	0.511	0.512	0.401	0.301	0.288	2.42	2.15	2.38	2.72	10.62
Amorpha	0.860	0.525	0.521	0.538	0.444	18.00	14.66	11.93	12.45	10.39
Birch	0.531	0.430	0.442	0.430	0.274	12.07	8.62	11.22	9.11	5.86
Aspen	0.713	0.602	0.611	0.554	0.361	10.26	9.72	7.79	6.31	4.08
Oak	0.892	–	0.892	0.438	0.191	18.45	—	25.40	6.96	2.67
Larch	0.428	0.317	0.317	0.307	0.228	9.79	9.72	9.25	6.10	3.54
Hawthorne	0.729	—	0.612	0.723	0.438	11.03	—	8.47	10.00	5.52

(on the average 3%-5%) at the end of the growing season. The sharp decrease in potassium content is the result of the gradual increase in ash content in leaves and also of the decrease in absolute potassium content in leaves.

What has been stated previously is corroborated by Table 5, showing potassium content in leaves of plants growing in pine plantations. The total potassium content in young leaves in all forest types is considerably higher than in species growing in the nursery, where it attains 1.8% of the air-dry weight of leaves; in no species is it lower than 0.85%. In this case a metric ton of air-dry leaves contains on the average 13.5 kg of potassium.

The rates of increase and decrease in potassium content agree with those observed in the nursery. Potassium content in dying leaves is higher in this case than in the nursery. It is not lower than 0.25%; on the average it is about 60% of the initial content. Thus, when more potassium is available to plants, they divert a minor part of it for re-use. Potassium content in ashes is also somewhat higher here.

During the initial period of leaf growth, the amount of potassium in ashes is up to 23.4%. The differences in the amounts accumulated can be seen, for example, in mountain ash growing in all investigated plots. At the beginning of the growing season its ash content was 9.8% in the nursery; in the pine-Vaccinium forest, 13.8%; in the pine-euonymus forest, 14.2%; and in the pine-basswood forest, 17.6%. The same holds true for other species.

The amount of phosphoric oxide within the leaves of various species growing within the nursery is shown in Table 6. Phosphoric oxide content in air-dry leaves is considerably lower than their potassium content and it varies between 0.13% and 0.33%.

The change in phosphoric oxide content in leaves is rather peculiar. At the beginning of the growing season it is high; in July and August it decreases, often to 40% of the initial content (Amorpha, aspen) and in September and October it begins to increase again until it almost equals the initial content. Thus, in addition to the first spring maximum of phosphorous requirement, there is a second, summer-autumn maximum, preceded by a migration of phosphorus during the second phase of growth. This peculiarity is important because almost all phosphorus accumulated during the first period subsequently disappears when leaves drop off. Table 6 also shows that the higher the phosphorous content in leaves, the more it decreases during summer; at low phosphorous content the decrease is relatively less. Thus, for example, in Amorpha containing 0.33% of phosphoric oxide (in air-dry leaves), in the middle of summer its content decreases to 0.1%, i.e., more than three times; simultaneously in mountain ash these amounts are, respectively, 0.14% and 0.12%; in larch, 0.16% and 0.14%; there has been a decrease of only 0.1%. It should be mentioned that, when

Table 5

Potassium content in leaves of trees and shrubs growing in pine plantations (collection 1956)

Species	Experimental Plot No.	Potassium in % of air-dry leaf material					Potassium in % of ash content				
		May 27	July 1	Aug. 5	Sept. 5	Oct. 7	May 27	July 1	Aug. 5	Sept. 5	Oct. 7
Mt. ash	7	1.802	0.960	0.949	0.730	0.442	13.75	7.88	11.20	8.65	5.63
	4	1.176	0.773	0.913	0.790	0.725	14.23	8.38	8.40	8.26	7.14
•	5	1.485	1.423	1.180	0.858	0.742	17.59	15.13	11.23	8.80	6.52
Alder buckthn.	7	1.395	1.365	1.438	1.454	0.877	21.81	17.80	18.47	18.05	9.60
	4	—	1.656	1.462	1.458	1.080	—	22.00	15.14	15.63	9.95
Hazelnut	4	0.924	0.724	0.684	0.740	0.810	10.57	8.23	6.92	7.35	7.17
	5	1.240	0.962	0.815	0.779	0.656	15.56	9.95	7.77	8.35	6.72
Euonymus	4	1.745	1.130	0.953	0.941	0.739	23.35	14.56	9.42	9.03	7.78
	5	1.202	1.142	1.283	1.228	1.103	16.55	12.89	12.53	11.64	8.87
Basswood	5	1.740	1.835	1.660	1.308	0.888	19.35	23.25	18.85	15.39	7.82
Maple	5	1.785	1.055	0.927	0.875	0.568	20.40	15.73	11.85	10.79	5.53
	4	—	0.867	0.899	—	1.083	—	11.54	10.16	—	8.77
Honeysuckle	4	—	1.385	1.396	1.093	1.623	—	13.76	8.47	6.93	10.75
Dogwood	4	0.848	0.727	0.709	0.718	0.648	8.70	5.97	4.65	4.61	4.23
Birch	7	0.927	0.611	0.524	0.416	0.354	12.98	9.72	8.35	5.92	6.57
Aspen	7	1.391	0.914	0.921	0.893	0.359	14.36	9.76	11.05	9.15	3.84
Gray willow	7	1.386	1.111	1.078	1.023	0.427	15.07	15.00	11.64	9.54	4.14
Oak	7	—	0.735	0.599	0.552	0.247	—	15.13	11.00	8.90	3.81

Table 6

Phosphoric oxide content in leaves of trees and shrubs growing in the nursery of the Bryansk Experiment Forest Station (collection 1956)

Species	Phosphoric oxide in % of air-dry leaf material					Phosphoric oxide in % of ash content				
	June 10	July 12	Aug. 4	Sept. 1	Oct. 1	June 10	July 12	Aug. 4	Sept. 1	Oct. 1
Mountain ash	0.136	0.138	0.124	0,165	0.161	3.01	2.81	2.12	2.88	2.34
Alder buckthorn	0,248	0.239	0.202	0.221	0.234	4.49	5.05	4.05	4.20	3.59
Basswood	0.206	0.195	0.196	0.165	0.184	2.80	2.31	2.01	1.92	2.14
Hazelnut	0.133	0.139	0.142	0.246	0.362	1.77	2.04	1.76	3.24	3.91
Honeysuckle	0.333	0.196	0.213	0.253	—	6.13	3.97	3.12	3.30	—
Euonymus	0.325	0.248	0.244	0.264	0.389	2.95	2.48	2.74	2.24	3.07
Barberry	0.216	0.171	0.298	0.151	0.370	4.97	3.92	5.42	3.38	4.95
Tatar maple	0.248	0.140	0.147	0.214	0.201	6.16	3.51	2.94	4.35	3.33
Service berry	—	0.188	0.174	0.212	0.266	—	3.43	3.24	3.64	4.47
Privet	0.206	0.158	0.136	0.198	0.182	6.51	5.58	5.59	4.60	4.07
White dogwood	0.281	0.212	0.267	0.214	0.251	2.74	2.44	3.36	2.30	2.36
Red elder	0.319	0.284	0.195	0.222	0.281	3.26	2.62	1.64	1.74	1.84
Yellow acacia	0.282	0.280	0.196	0.417	0.234	3.83	3.62	2.06	3.89	2.31
Cherry	0.234	0.194	0.152	0.177	0.195	5.08	3.89	3.23	3.15	2.97
Pine	0.145	0.125	0.074	0.072	0.130	4.70	5.17	3.44	3.02	4.79
Amorpha	0.329	0.200	0.139	0.098	0.144	6.87	5.59	3.19	2.27	3.37
Birch	0.183	0.226	0.229	0.231	0.268	4.16	4.54	5.83	4.89	5.74
Aspen	0.244	0.194	0.145	0.136	0.163	3.51	3.13	1.85	1.56	1.84
Larch	0.164	0.139	0.160	0.221	0.205	4.75	4.26	4.67	4.40	3.19
Oak	0.258	—	0.190	0.193	0.189	5.34	—	5.41	3.07	2.73
Hawthorne	0.232	—	0.160	0.176	0.186	3.51	—	2.22	2.43	2.34

leaves drop off, the content in phosphorus does not increase to the initial amount. The initial amount varies between 1.25% and 0.70%; for 21 species it is on the average 1.06% and extremes are exceedingly rare. It is entirely possible that the differences are due to the lack of agreement of observational data on the maxima and minima of the phosphoric oxide content in the leaves of various species.

The relative content in phosphoric oxide in leaf ash does not go beyond 6.8%, while at the same time, the content in potassium is 18.5%. The changes in phosphoric oxide content in ash during the growing season are not very apparent, as they are masked by the steady increase in ash content of the leaves. In autumn the phosphoric oxide content within ash decreases to 0.5%-0.6% of the initial content (oak, aspen, elder).

Phosphoric oxide content in the leaves of species growing in pine plantations was higher than in those growing in the nursery (Table 7). Thus, for example, phosphoric oxide content in the leaves of mountain ash growing in the nursery was 0.136%; in this same plant growing in pine-Vaccinium forest it was 0.188%; in the pine-basswood forest 0.262%; in the pine-euonymus forest 0.276%. Phosphoric oxide content varies during the growing season even in species growing in the nursery. It decreases in mid-summer (July-August) and sometimes in September (basswood). The second maximum in autumn is also very distinct. The degree of decrease in phosphoric oxide during summer varies; in special cases it is considerable (hazelnut in the pine-euonymus forest; aspen in the pine-Vaccinium forest). In this case it is 60%-62%. At times it is less, about 30% (honeysuckle in the pine-euonymus forest). The restoration in phosphoric oxide content in leaves at defoliation is of the same magnitude as in the nursery (0.75%-1.25%), but in special cases it decreases to 0.37% (aspen). On the average it is about 0.9% of the spring content for 18 species.

At the beginning of the growing season phosphoric oxide content in the leaf ash varies between 2.2% and 6.6% (on the average about 3.5%-4.5%). This is considerably lower in species growing in the nursery. This can be explained mainly by the high ash content of leaves and species growing in pine plantations. Because of the relatively small rate of increase in ash content in autumn, the peculiarities of change in phosphorous content in ash are rather distinct, but these changes are less conspicuous than in air-dry leaves. The relative content in phosphoric oxide in ash decreases sometimes to 0.4%-0.5% of the initial content.

Table 7

Phosphoric oxide content in leaves of trees and shrubs growing in pine plantations of the Bryansk Experimental Forest Station

Species	Experimental Plot No.	Phosphoric oxide in % of air-dry leaf material					Phosphoric oxide in % of ash content				
		May 27	July 1	Aug. 5	Sept. 5	Oct. 7	May 27	July 1	Aug. 5	Sept. 5	Oct. 7
Mountain ash	7	0.188	0.064	0.124	0.125	0.150	2.18	0.72	1.47	1.48	1.91
	4	0.276	0.286	0.278	0.330	0.296	3.34	3.10	2.55	3.45	2.91
	5	0.262	0.183	0.171	0.175	0.335	3.11	1.94	1.63	1.80	2.94
Alder buck-	7	0.396	0.235	0.196	0.232	0.254	5.77	3.06	2.52	2.87	2.78
thorn	4	—	0.364	0.415	0.421	0.392	—	4.84	4.30	4.50	3.61
Hazelnut	4	0.258	0.104	0.163	0.190	0.328	2.95	1.18	1.65	1.89	2.91
	5	0.251	0.092	0.226	0.192	0.364	3.15	1.06	2.16	2.06	3.18
Enonymus	4	0.381	0.320	0.185	0.325	0.337	5.09	4.12	1.83	3.12	3.55
	5	0.476	0.317	0.329	0.333	0.425	6.55	3.58	3.21	3.44	3.41
Basswood	5	0.383	0.159	0.168	0.146	0.330	4.25	2.02	1.91	1.72	3.19
Norway maple	5	0.370	0.239	0.264	0.241	0.310	4.26	3.56	3.38	2.97	3.02
	4	—	0.336	0.348	0.398	0.296	—	4.70	3.94	3.69	2.39
Honeysuckle	4	0.362	0.236	0.322	0.284	0.344	3.46	2.35	1.96	1.91	2.28
White dogwood	4	0.397	0.314	0.300	0.268	0.349	4.07	2.58	1.97	1.72	2.28
Birch	7	0.250	0.148	0.139	0.173	0.148	3.50	2.36	2.22	2.46	2.75
Asper	7	0.396	0.138	0.151	0.153	0.147	4.09	1.47	1.82	1.57	1.58
Gray willow	7	0.385	0.217	0.216	0.234	0.160	4.18	2.83	2.33	2.18	1.55
Oak	7	—	0.177	0.154	0.237	0.153	—	3.65	2.83	3.87	2.36

Our data show that plants have a high potassium and phosphorous requirement during the period of leaf development, i.e., at the beginning of the growing season. Furthermore, potassium migrates partially into other plant organs and during defoliation not more than half of the total accumulated in spring returns to the soil. It appears that the plant might be saving part of its potassium for the following spring. Phosphorus behaves differently in this respect, since notwithstanding its partial summer migration, its initial content within is replenished in leaves and thus returns to soil in its entirety. Therefore, the plant extracts as much phosphorus from the soil in spring, as it has deposited into it in autumn.

Together with the peculiarities of potassium and phosphorous requirement and return to soil, the behavior of these elements within the litter during autumn and winter, is of interest (from the end of one growing season to the beginning of the following one). During this time the transfer of ash elements from the soil into the plant is practically non-existent; simultaneously there occurs considerable precipitation, in the form of autumn rains and melt-waters which leach the litter and penetrate deep into soil. In the Bryansk forest this precipitation is about 240 mm.

In Table 8 potassium and phosphoric oxide content in fresh and wintered-over litter is given for some species growing in the nursery. As the data indicate, potassium content in leaves decreased rapidly during winter from 0.88%-0.16% to 0.07%-0.03% of the weight of air-dry leaves; i.e., in the majority of species the amount of potassium remaining was 6%-8% (maximum 22%) of the initial content. During autumn and winter the litter loses from 78% to 94% of its potassium content. It should be mentioned that this amount is somewhat lower, since at this time both decomposition and leaching occurred, but the data given were calculated in relation to the remaining fraction of the litter. It is possible to assume that a considerable part of potassium, deposited into the soil in autumn, is irretrievably lost in soils having a small adsorption complex.

Phosphorus behaves similarly. During autumn and winter its content in air-dry leaves decreased from 0.36%-0.14% to 0.11%-0.03% and in the litter of the majority of tree and shrub species it was 10%-12% (maximum 37%) of the initial content. Its almost total leaching from sandy soils is even more probable than that of potassium, since phosphorus is adsorbed even less than the other ash elements into the adsorption complex and its fixation in the soil, as poorly soluble calcium and magnesium salts, is prevented by the highly acid medium and the small amounts of calcium and magnesium.

From what has been said, it is possible to conclude that a more rapid decomposition of litter during autumn and winter and the leaching

Table 8

Potassium and phosphoric oxide in fresh and over-wintered litter of trees and shrubs growing in the nursery of the Bryansk Experimental Forest Station (collection 1956)

Species	Potassium content, %					Phosphoric oxide content, %				
	Fresh		Over-wintered		Remaining on air-dry litter basis	Fresh		Over-wintered		Remaining on air-dry litter basis
	Litter					Litter				
	Litter basis	Ash basis	Litter basis	Ash basis		Litter basis	Ash basis	Litter basis	Ash basis	
Mt. ash	0.239	3.47	0.048	0.39	11.2	0.161	2.34	0.107	0.87	37.22
Alder buckthn.	0.164	2.52	0.048	0.22	8.7	0.234	3.59	0.082	0.37	10.35
Service berry	0.440	7.40	0.049	0.46	6.2	0.266	4.47	0.092	0.85	19.11
Maple	0.364	6.03	0.062	0.53	8.7	0.201	3.33	0.034	0.29	8.75
Honeysuckle	0.096	2.16	0.041	0.32	14.6	0.182	4.07	0.084	0.65	10.61
Yel. acacia	0.732	7.32	0.062	0.49	6.8	0.234	2.31	0.096	0.77	34.65
Elder	0.876	5.73	0.035	0.11	19.7	0.281	1.84	0.070	0.23	12.33
Amorpha	0.444	10.39	—	—	—	0.144	3.37	0.083	0.81	23.90
Cherry	0.364	5.54	0.046	0.39	7.0	0.195	2.97	0.055	0.46	15.55
Hazelnut	0.444	4.80	0.050	0.48	9.9	0.362	3.91	0.055	0.53	13.47
Larch	0.228	3.54	0.056	0.79	22.3	0.205	3.19	0.044	0.63	19.80
Hawthorne	0.438	5.52	0.074	0.58	10.5	0.186	2.34	0.065	0.51	21.79

of potassium and phosphorus from the root zone, is the negative factor from the viewpoint of re-utilization of the ash elements for plant growth. For this purpose a slow decomposition would be more appropriate. But a very slow decomposition, which would bring about a concentration of large amounts of ash elements, is also undesirable.

Moreover, this study shows that forest topsoil, especially its lower subhorizon, plays an important part in the accumulation of elements leached out of the litter. This layer has a high exchange capacity (150-160 meq) and has the ability to accumulate these elements in a form available to plants. When litter decomposes rapidly, the topsoil layer is thin, with a poorly developed subhorizon A_0^3 and, thus it is unable to keep the ash elements which are set free.

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